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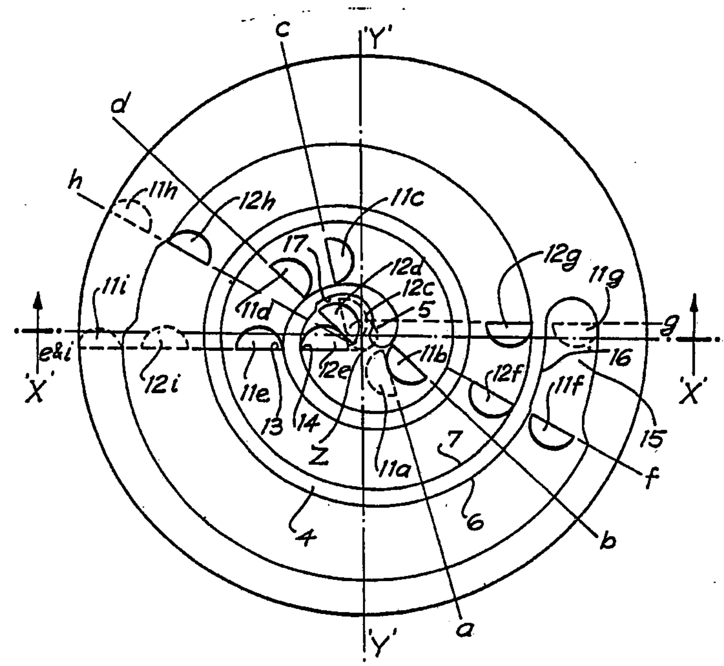

(57) Abstract

A method of finish machining surfaces of a preformed multi-turn involute spiral wrap of a scroll type compressor in which the wrap (4) is rotated about the axis (3) of the base circle (5) of the involute spiral and a single point cutting tool is applied to one or both faces of the wrap (4) and as the wrap rotates the tool/tools is/are traversed in a direction tangential to the base circle (5) the traverse of the tool/tools per revolution of the wrap (4) being equal to the circumferential length of the base circle (5) whereby a strip of material is removed from the wrap (4) over its full length, these steps being repeated until the whole surface or surfaces of the wrap (4) is/are finish machined to leave a surface finish consisting of a series of smooth and continuous spiral surfaces lying side by side.

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METHOD OF MACHINING SCROLL COMPONENTS

BACKGROUND TO THE INVENTION

This invention relates to scroll type gas compressors, and to a means of manufacturing the components parts of such compressors, which term is to be taken to include pumps.

Scroll-type compressors are well known in the art of refrigeration apparatus, air compressors and the like. In some cases such scroll-type devices are used for the expansion of gases rather than compression, and it follows that the invention equally relates to the manufacture of such devices.

For example US patent 4441870 shows a typical device which has two scrolls, each having a circular end-plate and an involute spiral wrap protruding therefrom, longitudinally with respect to an axis normal to the plane of the associated end-plate.

Typically, when used in refrigeration apparatus the spiral wraps each have about 2 1/2 to 3 turns. The scrolls are of opposite hand but, when placed face to face, and offset one to the other, the inner and outer surfaces of the spiral wraps contact and slide on each other to define a series of pairs of diametrically opposed chambers whose volume is largest for the most remote from the centre line of the circular end plates and smallest for those adjacent to centre line. When the longitudinal axis of one scroll is moved with an orbital motion with respect to the longitudinal axis of the other, the larger chambers become progressively smaller and so compress the gas trapped therebetween. A central hole in one circular end plate allows the compressed gas to escape from the smallest chamber, while fresh charges of gas are entrapped by the outer portions of the scroll wraps in the largest chambers.

Because the compression of the gas occurs

progressively over 2 1/2 orbital motions or stages, the pressure drop from chamber to chamber is only a fraction of the total pressure drop from the inlet to the outlet, and hence gas leakage from chamber to chamber is reduced.

Notwithstanding this, great precision must be achieved in the manufacture of the scroll wraps, both in regard to the inner and outer spiral wrap surfaces and to the end plate surfaces, and a good surface finish must be achieved so that sealing occurs between the chambers notwithstanding that there is only line contact between the spiral wrap surfaces.

Such scrolls are generally formed from a single piece of metal, which may typically be of cast iron or aluminium, generally rough-shaped by casting and thereafter milled with an end-milling type cutter. For example, US Patent 4441870 describes the use of the milling cutter of the end-mill type which is caused to move in a spiral path and to simultaneously mill the opposing wrap faces and end-plate face at the bottom of the wraps. In the patent, the limitations imposed by the use of a milling cutter of the same width as the gap between the spiral wraps are addressed, particularly in regard to the shape of the innermost turn.

US Patent 4463591 advocates the use of a coining technique to precisely finish the inside and outside wrap surfaces and the end-plate faces at the bottom of the wraps. The patent seeks to overcome the limitations imposed by the widely used milling technique.

Still another method of manufacturing scroll pump components is described in US Patents 4436465 and 4615091, and the limitations and inefficiencies of the end-milling method are described. Particular reference is made to the poor finish and accuracy, and the long machining time required by milling. These patents propose axial broaching by a continuous spiral broach tool in order to

finish machine the inner and outer wrap surfaces, the first of the two patents by direct broaching, and the latter using an ultrasonic reciprocation of the tool.

Notwithstanding the above attempts to provide an improved process to replace end-milling, so far it appears that substantially all scroll pump components are produced by end-milling.

Thus milling the wrap faces by traversing them with a cylindrical surface of an end-milling cutter, which inevitably produces a rough profile of inferior accuracy, is still universally employed.

A typical end-milling cutter will have 8 or 10 cutting edges and, as it traverses a curved surface, will produce a profile on the wrap faces comprising a series of cusps. All such cutters will, inevitably, have some eccentricity, so that such cusps will undulate every 8th or 10th cusp. Both these features, namely the cusps and the undulations thereof will, in general, be parallel to the longitudinal axis of the scrolls and hence at right angles to the direction of relative sliding therebetween.

Now the contacts between the wrap faces may be likened to those between a shaft and a surrounding journal, and the surface finish of such parts, as in the case of a shaft and journal, is optimum surface irregularities as inevitably occur extend in the direction of sliding and not at right angles thereto, the former situation promoting the entrainment of lubricant between the two surfaces.

The deleterious effects of the end milling process can be reduced by using a very slow feed rate, but the time taken to machine each scroll is increased. Also because the cutter is engaged with the wrap for its full depth during machining, considerable side forces are produced, leading to deflection of the wrap at its outer end, and less deflection towards its root. This

deflection pattern results in a wrap having a concavity along its length when viewed in section of a magnitude depending on the sharpness of the cutter which is continually changing from piece to piece. It follows that no practical way of compensating for this error is possible. If, as taught in US Patent 4441370 the end-mill is made of the exact width of the space between the wraps, then only one pass of the cutter is required in that opposing wraps are machined simultaneously. However, such an end-mill cannot be sharpened on its outer cutting surface without loss of space width, and so has very limited life.

The axial broaching methods described in US Patents 4436465 and 4615091 will also produce a surface finish with surface irregularities parallel to the longitudinal axis of the scrolls and hence is also unsuited to achieving smooth journal-like sliding.

Now it is well known in the art of gearing that an involute surface, such as the flank of a gear tooth of great precision and excellent finish may be generated by rolling the gear tooth in contact with a flat generating surface, e.g. a grinding wheel. This method is not possible in machining scroll compressor components because of the multi-turn nature of the involute surfaces.

BRIEF DESCRIPTION OF THE INVENTION

The present invention consists in a method of finish machining a surface of a preformed multi-turn involute spiral wrap of a scroll type compressor comprising the following steps:-

(a) mounting a multi-turn involute spiral wrap in a holding device adapted for rotation;

(b) rotating the wrap about the axis of the base circle of the involute spiral;

(c) bringing a cutting tool into contact with a point on the surface of the wrap;

(d) simultaneously traversing the tool in a direction tangential to the base circle, the traverse of the tool per revolution of the wrap being equal to the circumferential length of the base circle whereby a strip of material is removed from the wrap over its full length;

(e) removing the tool axially from the wrap and bringing it into contact therewith at a point adjacent the first mentioned point and repeating step (d);

(f) repeating step (e) until the whole surface of the wrap is machined to leave a surface finish consisting of a series of smooth and continuous spiral surfaces lying side by side each of limited extension in the direction of the said axis.

In practice two separate tools may be arranged to cut opposing sides of the involute wraps in a series of cuts, each cut being displaced along the longitudinal axis with respect to the preceding cut, commencing at the end of the wrap and cutting successively deeper until the root of the wrap is reach, adjacent to the end-plate. Up to 100 cuts will be required, and a specific generating geometry must be employed in order to achieve true involute faces on the sides of the wrap. The scroll pump component will have been rough machined on the wrap faces to within .5 m/m of finish size in a prior operation.

The invention further consists in a scroll type gas compressor component consisting of a back plate having thereon a multi-turn involute spiral wrap characterised in that the wrap surfaces have a surface finish comprised of a series of smooth and continuous spiral surfaces lying side by side each being of limited extension in the direction of the axis of the base circle of the involute spiral.

Because the tool is engaged with the wrap for a small depth compared to the depth engagement when the entire surface of the wrap (say 30mm deep) is machined at once as

in the case of end-milling, the forces tending to deflect the wrap are greatly reduced (by a factor of 1/150 for the case stated here). Also the surface generated is smooth and continuous in the direction of relative sliding between the wraps, and the cusps produced by end-milling are avoided.

In a further refinement two such tools traverse the wrap simultaneously, one on either side thereof, so balancing these greatly reduced cutting forces, so that the net deflecting force is reduced substantially to zero. Note that the use of two tools cutting at once also halves the cutting time. This balancing of cutting forces cannot be achieved when milling because it is impractical to locate the milling spindles close enough.

Now it is well known in machining practice, particularly when using long-wear-life cutting tools such as tungsten carbide or diamond composite (crystallite), that a high surface speed must be used. The minimum speed appropriate for machining a typical scroll component would be about 300 rpm and, of course, it is impractical to stop the spindle carrying the scroll at the start and finish of each cut. It follows that, for a typical scroll component rotating continuously, the tool or tools must move axially into position to machine the scroll surface (a distance of up to 30mm for the case referred to), in no more than 1/8th revolution of the scroll, or in a time interval of 25 milliseconds. Also as the scroll surfaces start and end about half a turn apart the two tools must take up their position sequentially one-half revolution of the spindle part. At the least radius of the scroll the tool machining the outer surface will commence cutting one-half revolution before the tool machining the inner surface starts to cut, and the opposite will apply at the outer end of the scroll. Also the pair of tools should desirably return from the inner position to the outer

position or vice versa in the least possible time, e.g. 100 milliseconds.

In practice, where the scroll has 2 1/2 to 3 turns, each turning cycle takes about 0.8 seconds, and as 100 cuts are required, the entire wrap machining cycle will take about 80 seconds.

Several unique features of the machine to be described are directed at achieving these rapid movements reliably, repeatedly, and with great precision.

In a still further improvement, slight modifications to the geometry of the involute work surfaces are achieved to improve the sealing of the inner scroll surface contacts, where compression pressures are high, as compared to that of the outer scroll surface contacts. This improved sealing of the inner scroll contacts requires that the wrap is machined thicker for the inner scroll turns notwithstanding that the tools are preferably mounted on a single slideway and traversed by a single cam mechanism, in order to achieve the necessary accuracy. This is achieved according to the invention, by positioning the single point tools which machine the inner and outer wrap surfaces at slightly different heights with respect to a line tangent to the base circle.

Finally, according to the invention, a means is provided of machining the tops of the wraps and the bottom faces between the wraps before the scroll component is removed from the machine so achieving a precise relationship between all four surfaces which define the compression chambers. No other machining process achieves this objective.

Of course the machining of the component could be accomplished by holding the scroll component stationary and moving the tools relative thereto to accomplish the same relative movement.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a front elevation of a typical fixed scroll component.

Fig. 2 is a section on line XX of Fig. 1.

Fig. 3 is a front elevation of a typical moving scroll component.

Fig. 4 is a section on line XX of Fig. 3.

Figs. 5, 6 and 7 are part-sections of a fixed scroll component on various rays at different stages of machining.

Fig. 8 shows the milling operation of surfaces 8 and 9 (Fig. 2).

Figs. 9, 10 and 11 show machining of the scroll surfaces according to the prior art.

Figs. 12, 13 and 14 show machining of the scroll surfaces according to the invention.

Fig. 15 shows a schematic view of a machine according to the invention.

Figs. 16 and 17 show details of the cam operating mechanism of Fig. 15.

PREFERRED EMBODIMENTS OF THE INVENTION

Figs. 1 and 2 show the front elevation and section on XX of the fixed scroll of a scroll pump made according to the invention. It comprises circular end-plate 2 having axis 3 having formed integral with the circular end-plate a continuous spiral wrap 4. The spiral of wrap 4 comprises two involute surfaces generated from base circle 5 located on axis 3.

The origin of the involute curve of the outer spiral surface 6 lies on axis YY as indicated at z. The inner spiral surface is shown as 7.

The wraps terminate axially at their outer ends at surface 8 and at their inner ends at surfaces 6a and 7a which are geometrically similar but of opposite hand to those of fixed scroll shown in Figs. 1 and 2 when viewed towards the wraps.

As this invention deals only with the method of manufacture of the working surfaces of the fixed and moving scrolls, all reference to the journalling, gas and lubricant passages etc. which are addressed in many other patents will be omitted. Only those surfaces which are affected uniquely by the machining process will be described.

Referring now to Figs. 2, 5, 6 and 7 according to the method of finish machining to be described, the involute surfaces of wrap faces 6 and 7 are machined by two tools 11 and 12 respectively, while the scroll is rotated in a clockwise direction. The tools are mounted on a slideway and are arranged so that their cutting edges, or points 13 and 14 respectively, move radially inwardly along lines tangent to base circle 5, which lines will be referred to as rays.

In order that the surfaces 6 and 7 are involute, the travel of tool points 13 and 14 are equal to 2IIr0 where r is the radius of base circle 5, and 0 is the angle of rotation of the scroll. For the outer surface machining tool point 13, point z, where 0 equals 0, is the point of origin of the involute. The involute surface of inner surface 7 lies at a lesser distance from the point of tangency an amount equal to the desired thickness of wrap 4.

Prior to commencing the finish machining operation, surfaces 6, 7, 8 and 9 will have been rough machined, precision cast or otherwise formed leaving an appropriate amount, say 0.3 to 0.8m/m for finish machining. Certain other preparatory machining may also be required as will be described later.

In order that the sequency of tool movements can be clearly understood, Figs. 2, 5, 6 and 7 show successive positions of tools 11 and 12 as though the scroll was fixed and the pair of tools rotated anti-clockwise, and

simultaneously moved along the respective rays. These rays are shown in Fig. 2 as a, b, c, d, e, f, g, h, i, each tangent to base circle 5. The machining cycle commences when tool 11, which machines the outer wrap surface 6, lines on ray 1 and commences to move axially and radially outwardly. Note that, in Fig. 2 the tools are shown in dotted outline when they are retracted and clear of the scroll. After rotation of about 30 degrees (ray b), this tool reaches a position as shown at 11b, Fig. 1, where the first involute spiral cut commences.

One half turn later (rays c and d), the events just described in reference to the outer wrap tool 11 occur in respect of the inner wrap surface tool 12. That is (at ray c) tool 12 commences to move axially and radially outwardly and at ray d will have reached the same depth of engagement as tool 11, which situation is illustrated in Fig. 6.

As stated earlier, the cutting sequence now being described is repeated up to 100 times, each cut being successively deeper. For example, in Fig. 5, the position of tools 11e and 12e is shown about half way down on wrap 4. On ray f, tool 11 will have completed its cut along wrap face 6 and will commence a rapid retract movement so as to clear the scroll face 8 by ray g. Pocket 15 and clearance recess 16 are provided so that tool 11 may rise clear of the scroll without machining contact therewith. Meanwhile, tool 12 continues as at 12g.

At ray h, tool 12 will have completed its path along wrap face 7 and starts its retract motion while tool 11 is axially stationary and clear of face 8 as at 11h. Both tools are clear of the scroll surface 8 at ray i as shown in Fig. 5 and commence rapidly returning to the centre of the scroll so as to commence re-entry of the scroll at ray a.

A pocket will be required to provide for entry of the

tools, particularly for tool positions 12d and 12e, where the tool must rapidly move axially to take up its position during rotation of about 30 degrees. Clearance recess 17 is provided for this purpose. The high rate of retraction of the tools is particularly important where the full depth is reached as in Fig. 7. Here it will be seen that tools will have moved beyond the rough machine surface 9 at the base of the wraps, leaving a raised annular surface 18 to be subsequently machined by milling.

The annular raised surface 18, together with entire material on surface 8 left on for finish machining is removed by a double surface milling cutter 19 shown in Fig. 8. This cutter rotates at a high speed and finish mills both surfaces to an identical depth to the turned face produced by tools 13 and 14 as shown in Fig. 8, as will be further explained.

In Figs. 9 to 14, the process of milling the side faces of the wraps are compared with the single point generation and face milling process according to the invention. Figs 9 and 10 show a typical 8 fluted end milling cutter which mills one side of wrap 4 and the bottom face 9. The finish produced by such a cutter is shown in Fig. 11, and will be characterized by having a series of cusps on which is superimposed undulations corresponding to each rotation of a cutter, due to the eccentricity thereof.

Figs. 12, 13 and 14 show, by way of comparison, the involute generating process according to the invention. The surface finish produced by the process is illustrated in Fig. 14, and consists of a series of involute lines parallel to the end face 9.

The machining of fixed and moving scrolls 2 and 2a is carried out, according to the invention, on the machine shown in Fig. 15. Here, the scroll component is held by chuck means 20 mounted on spindle 21 carried in

journals 22 and 23 supported on machine base 24. Spindle 21 is rotated by worm wheel 25 driven by worm 26 carried by shaft 27 which rotates in journals (not shown) carried by machine base 24. Shaft 27 is rotated by motor 28 secured to a bracket 29 also mounted on machine base 24. Shaft 27 is extended to carry worm 28 which drives worm wheel 29 secured to lay shaft 30, which is journalled on a bracket 31 protruding from machine base 24. Lay shaft 30 incorporates spline 32 which slides axially in the internally splined end of shaft 33 which is journalled in bracket 34 and incorporates bevel gear 35 which drives bevel gear 36 mounted on stub shaft 27.

Spindle 21 extends rearwardly to carry master cam 38 having a scroll recess 39 cut into one face, and a scroll of the opposite hand cut in the reverse face (not shown).

Engaged in scroll recess 39 is cam follower 40 mounted on lever 41 secured to rocking and sliding shaft 42, which is journalled to the machine base 24 at journals 43 and 44. Rocking and sliding shaft 42 has, at the front end of the machine, lever 45, which serves to control movements of tools slideway 46.

Tools 11 and 12 protrude forwardly towards the scroll, and are mounted on toolslides 47 and 48 which are carried on precision slideways in tool box 49 which is rigidly mounted to tool slideway 465.

The entire function of toolslides 47 and 48 is to provide for the rapid advance and retract of tools 11 and 12 as required by their engagement with the scroll during the machining operation. In every case their forwardmost position is the same with respect to tools slideway 46 or tool box 49, and the end position is controlled by an accurate stop (not shown).

The depth of the machining cut performed by tools 11 and 12 is controlled by the axial position of main slideway 50 which is moved along the slideway 51 of

machine base 24 by lead screw 52 driven by numerically controlled electric motor 53.

Main slideway 50 has attached to it bracket 34 which provides a journal for shaft 33 and also a mounting for stub shaft 37. Thus stub shaft 37, bevel gear 36, bevel pinion 35 and shaft 33 all move axially, i.e. in the direction of the axis of spindle 21, upon longitudinal motion of main slideway 50.

The advance and retract movements of tools 11 and 12 are controlled by shafts 54 and 55 each of which rotate through a limited angle as determined by a cam track 56 incorporated in the face of bevel gear 36. Thus shaft 54 extends and is journalled in bracket 57 which forms part of bracket 34 attached to main slideway 50. Shaft 55 is also journalled in bracket 57. Shafts 54 and 55, at their outer extension, carry bell-crank levers 58 and 59 respectively having integral therewith pins engaging cam track 56.

Now it is arranged that the total gearing relation between spindle 21 and bevel gear 36 is such that, when spindle 21 makes four revolutions, bevel gear 36 makes one revolution. It will be seen that cam track 56 comprises a segment of small radius as at 60 and a segment of large radius as at 61 being joined by two steeply-sloping ramps. As bevel gear 36 rotates in a clockwise direction it follows that the events determined by cam track 56 will occur first on shaft 54 and subsequently on shaft 55. Because the angle 63 subtended by the pivots of levers 58 and 59 about the axis of the stub shaft 39 is arranged to be 45 degrees, it follows that, in respect of the rotation of spindle 21, these events will occur spaced 180 degrees in respect of rotation of spindle 21, it follows that the rapid advance and retract motion of tools 11 and 12 will occur 180 degrees with respect to rotation of the scroll being machined.

It will be recollected that such a sequence is required of the movement of the tools as explained in reference to Figs. 1 and 2.

The longitudinal movement of tool slideway 46 will require that shafts 54 and 55 incorporate axially sliding splines, in that bell crank levers 58 and 59 are fixed axially, whereas the sections of the shafts 54 and 55 shown in Fig. 15 are required to move with travel of the slideway 46.

Now referring to the function of lever 45, it will be seen that its cylindrical end 64 engages a slot in tool slideway 46 so that as rocking motion occurs of rocking and sliding shaft 42 is caused to travel in a manner determined by master cam 38 and lever 41.

It will be seen that a second notch 66 is provided in the underside of tool slideway 46 the function of which will be later described.

In order that the sequence of operations referred to earlier as occurring about one hundred times takes place smoothly during continuous rotation of spindle 21 special provision is made as will now be described to control this sequence of events. Thus rocking and sliding shaft 42 carries at its remote end both lever 41, shift lever 67, and retract lever 68, all of which are secured rotationally and axially to rocking and sliding shaft 42.

Details of the functions of this mechanism are illustrated in Figs. 16 and 17. Here it will be seen that cam 38 has on its forward face scroll recess 39 and, as mentioned earlier, on its reverse face scroll recess 69 of the opposite hand. Both scroll recesses terminate at their inner and outer ends respectively in recesses of constant radius as indicated at 70 and 71 respectively. Retract lever 68, in Fig. 16, lies directly behind lever 41, as also does cam follower 72.

It will be seen that, in Fig. 17, cam follower 74

lies clear of the rear face of master cam 38 and therefore is free to move across the face of the cam without engagement in scroll recess 69. This is the situation in Fig. 15 where rocking and sliding shaft 42 together with its respective levers 45, 41, 67 and 68 has just moved rearwardly to carry cam follower 40 into the inner circular section of scroll recess 39 as indicated at 70, and machining of the scroll is about to commence.

After approximately two revolutions of the spindle, follower 40 will have reached the arcuate section 71 of cam track 39 and it is required that slideway 46 return to its starting position rapidly. For this purpose rocking shaft 42 is moved axially towards the front of the machine carrying cam follower 74 mounted on retract lever 68 into the retract slot 69 in the back face of the master cam. Thereupon after one further revolution of the master cam and spindle the lever returns to the innermost position illustrated in Fig. 16 whereupon rocking and sliding shaft 42 is moved rearwardly to re-engage cam follower 46 in scroll recess 39. This rapid axial movement of the shaft is effected by the engagement of cams 72 and 73 secured to the periphery of master cam 38 which engage pins 75 and 75a which extend from shift lever 67. The bevelled faces of these cams serve to rapidly thrust rocking shaft 42 axially and so result in the sequence just described.

As mentioned earlier, the machine provides also to machine faces 8 and 9 upon the completion of the turning operation just described. For this purpose milling cutter 19 is provided, as shown in Fig. 8 and also in Fig. 15 mounted in milling head 77 carried by tool slideway 46 to the rear of tool box 49. It is driven by a motor or similar means not shown.

Tool slideway 46 is provided with a nut not shown which engages ball bearing lead screw 78 driven by

numerically controlled electric motor 76 which is secured to the rear end of the main slideway 50.

During normal motions of the tool slideway 46, as during the turning operation sequence, motor 76 spins freely as it is not energized during this phase.

However, on completion of the machining of the scroll faces, it is provided that numerically controlled electric motor 53 fully retracts main slideway 50 to such a degree that lever 64 escapes from slot 65, whereupon motor 76 is energized to move the tool slideway forwardly in order to bring milling cutter 19 into an appropriate position to machine faces 8 and 9 of the scroll. In this position, while motor 76 is suitably in position, motor 53 is energized to engage cylindrical portion 65 of lever 64 in slot 66 of the slideway in preparation for the commencement of the milling operation. The motor 28 is now energized to move the main slideway 53 to full depth position, as spindle is started and main motor 28 is energized to make a forward travel of the tool slideway under control of master cam 38. For this purpose, motor 28 rotates very slowly at a speed appropriate to the milling sequence. On completion of the milling, main slideway 50 is retracted under control of motor 53 so that the removal of scroll 2 can occur and the next component be loaded into the chuck means 20.

CLAIMS:-

1. A method of finish machining a surface of a preformed multi-turn involute spiral wrap of a scroll type compressor comprising the following steps:-

(a) mounting a multi-turn involute spiral wrap in a holding device adapted for rotation;

(b) rotating the wrap about the axis of the base circle of the involute spiral;

(c) bringing a cutting tool into contact with a point on the surface of the wrap;

(d) simultaneously traversing the tool in a direction tangential to the base circle, the traverse of the tool per revolution of the wrap being equal to the circumferential length of the base circle whereby a strip of material is removed from the wrap over its full length;

(e) removing the tool from the wrap and bringing it into contact therewith at a point adjacent the first mentioned point and repeating step (d);

(f) repeating step (e) until the whole surface of the wrap is machined to leave a surface finish consisting of a series of smooth and continuous spiral surfaces lying side by side each of limited extension in the direction of the said axis.

2. A method as claimed in claim 1 wherein two cutting tools are applied to opposite sides of the wrap whereby both sides are finish machined simultaneously.

3. A scroll type gas compressor component consisting of a back plate having thereon a multi-turn involute spiral wrap characterised in that the wrap surfaces have a surface finish comprised of a series of smooth and continuous spiral surfaces lying side by side each being of limited extension in the direction of the axis of the base circle of the involute spiral.

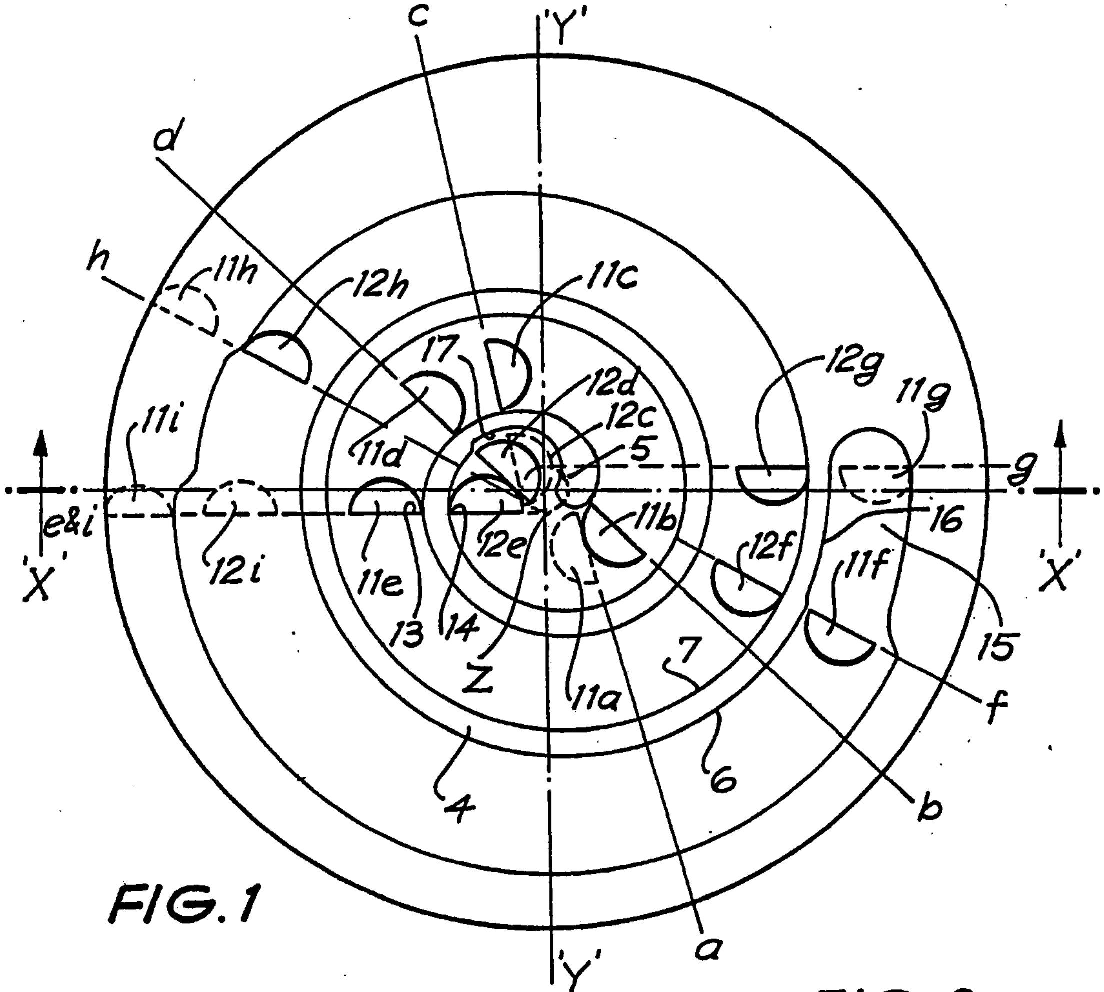
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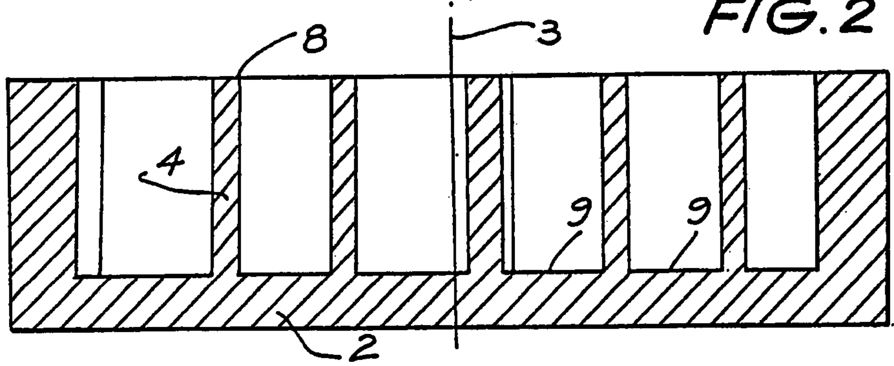
FIG.1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9
2

FIG.2

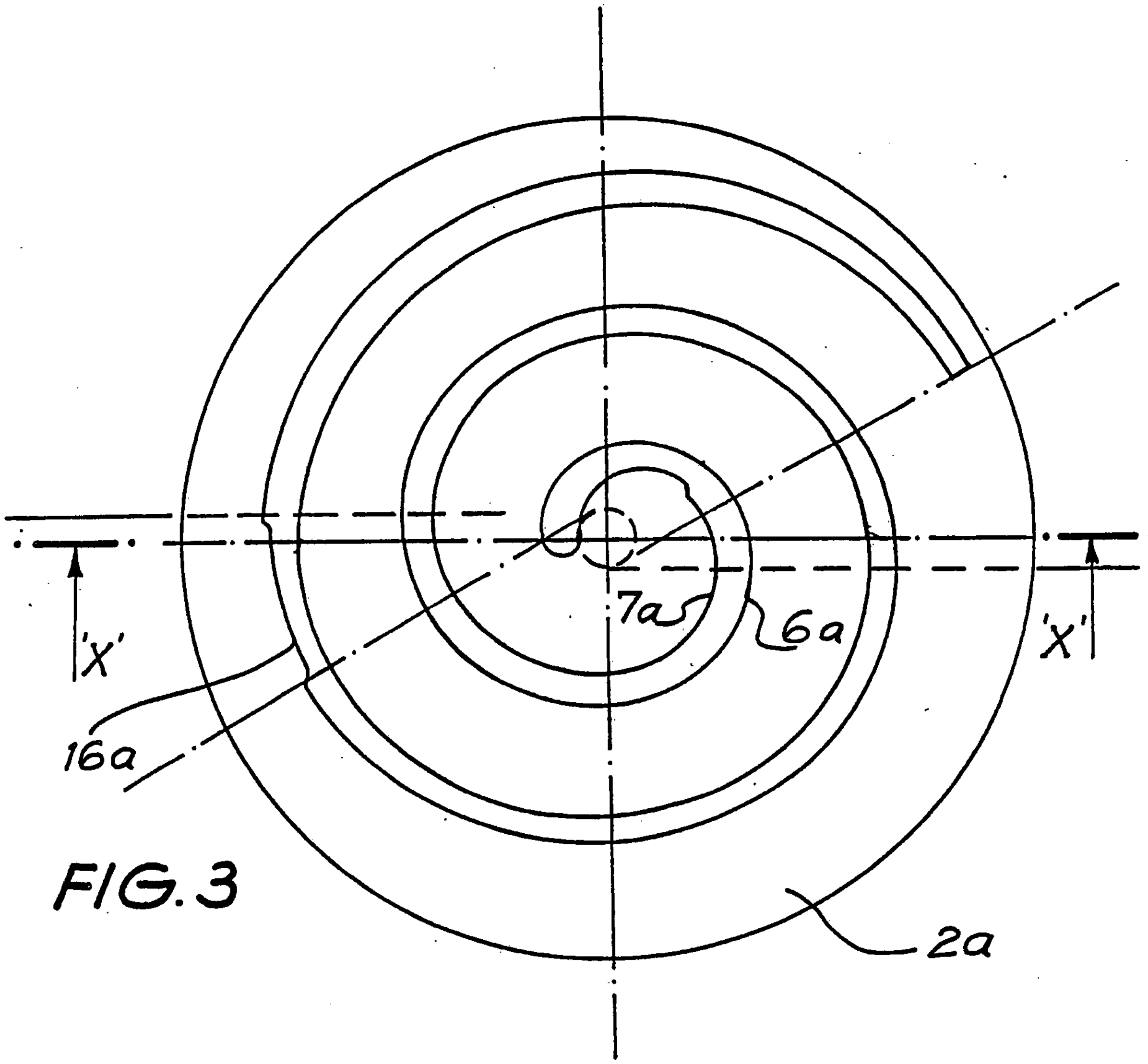
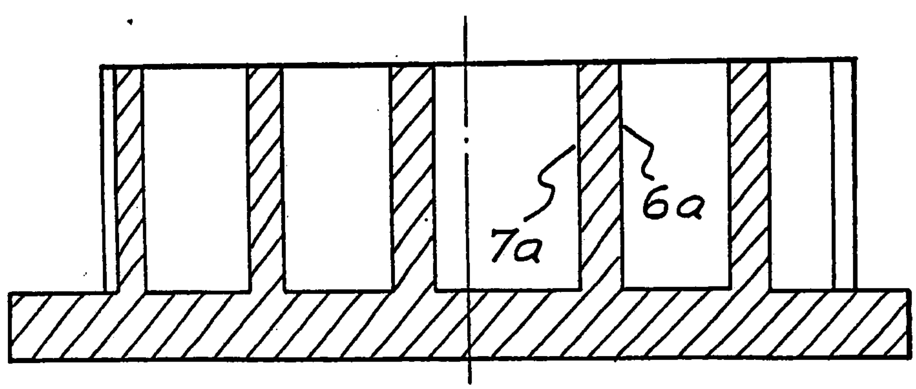


FIG.3

FIG.4



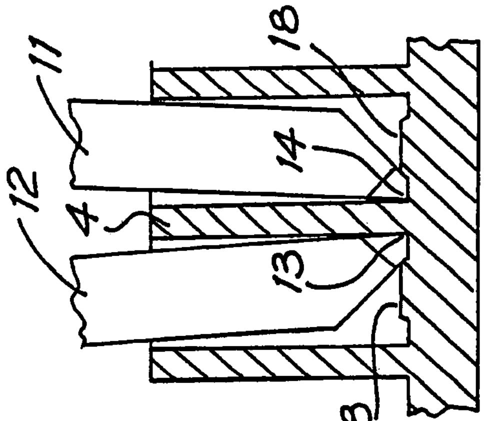


FIG. 7

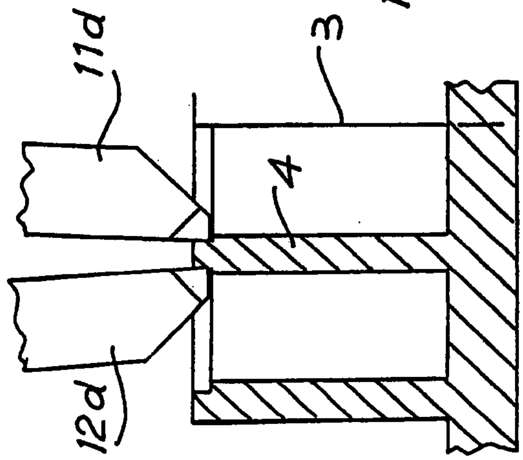


FIG. 6

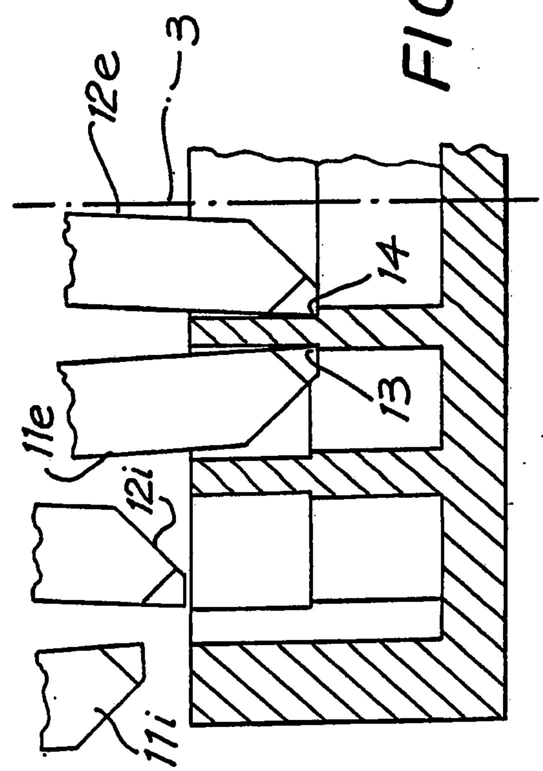


FIG. 5

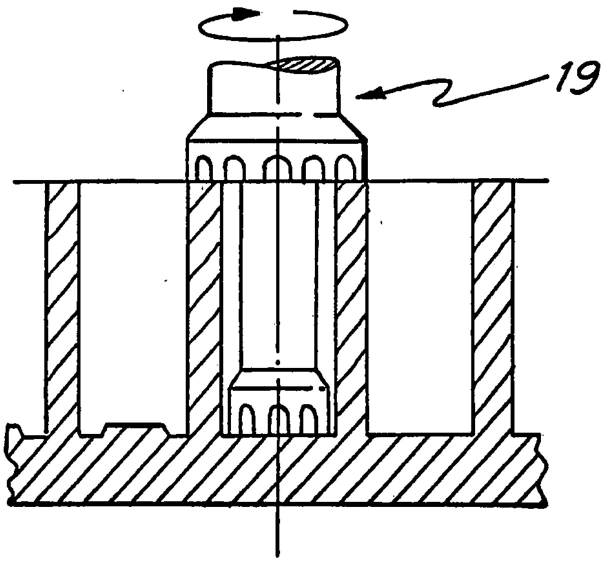


FIG. 8

FIG. 9

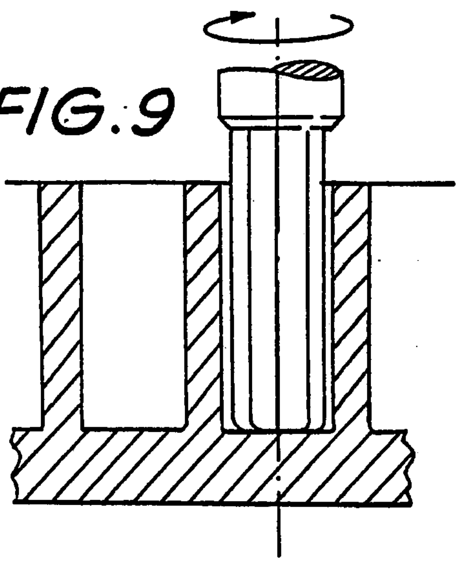


FIG. 10

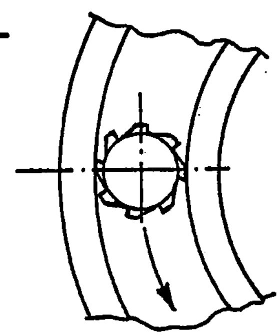


FIG. 11

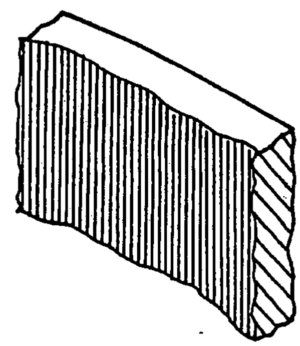


FIG. 12

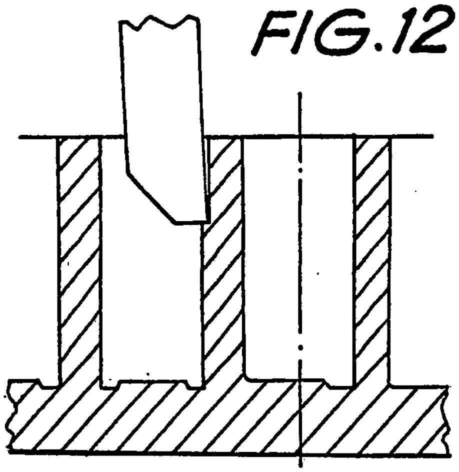


FIG. 13

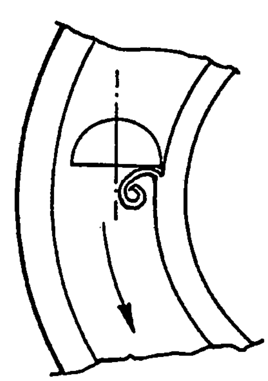
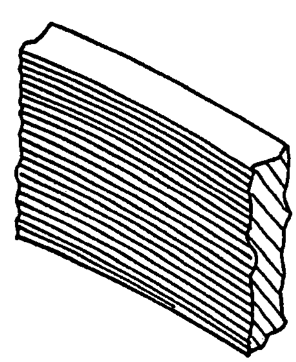


FIG. 14



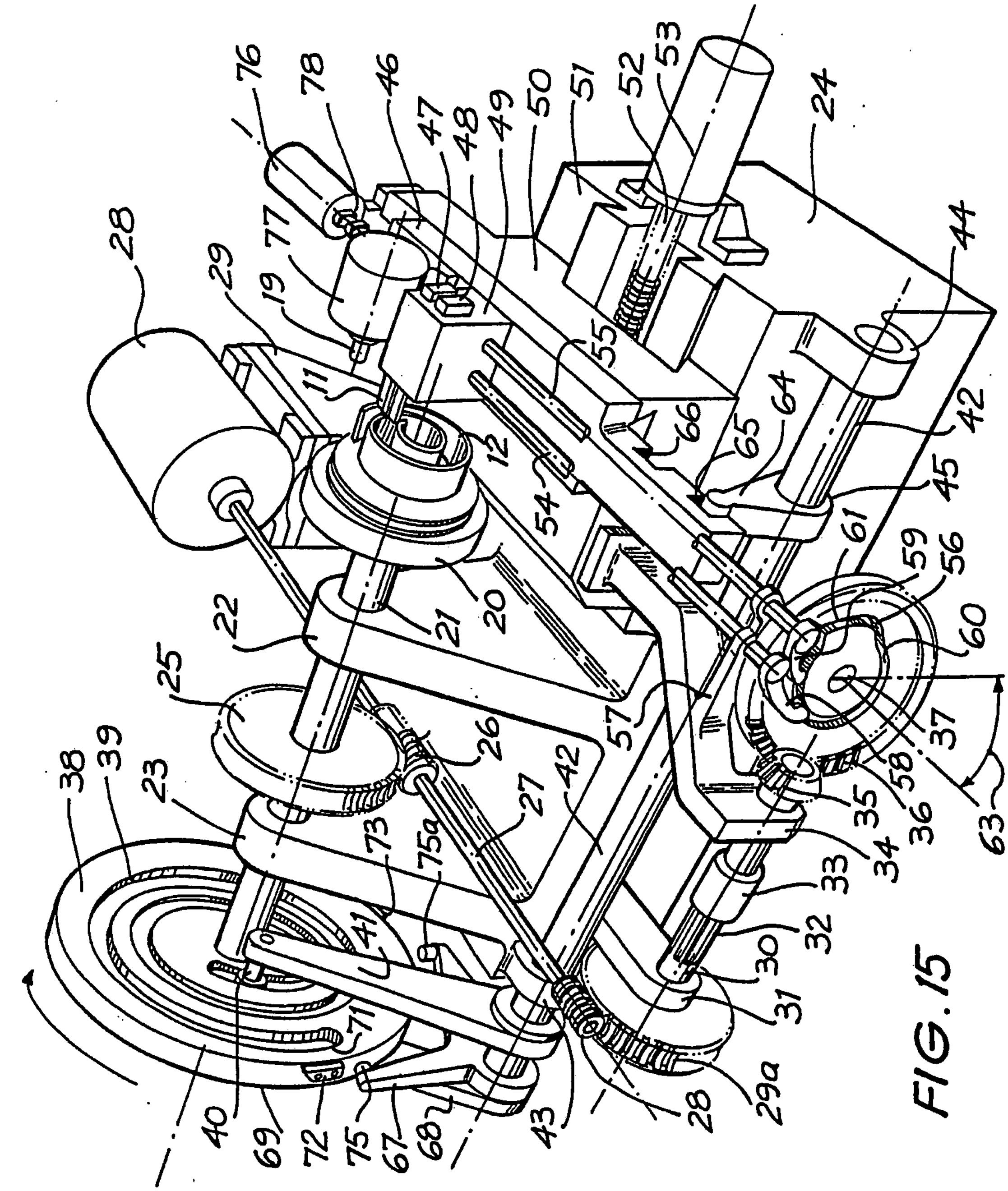

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FIG.15

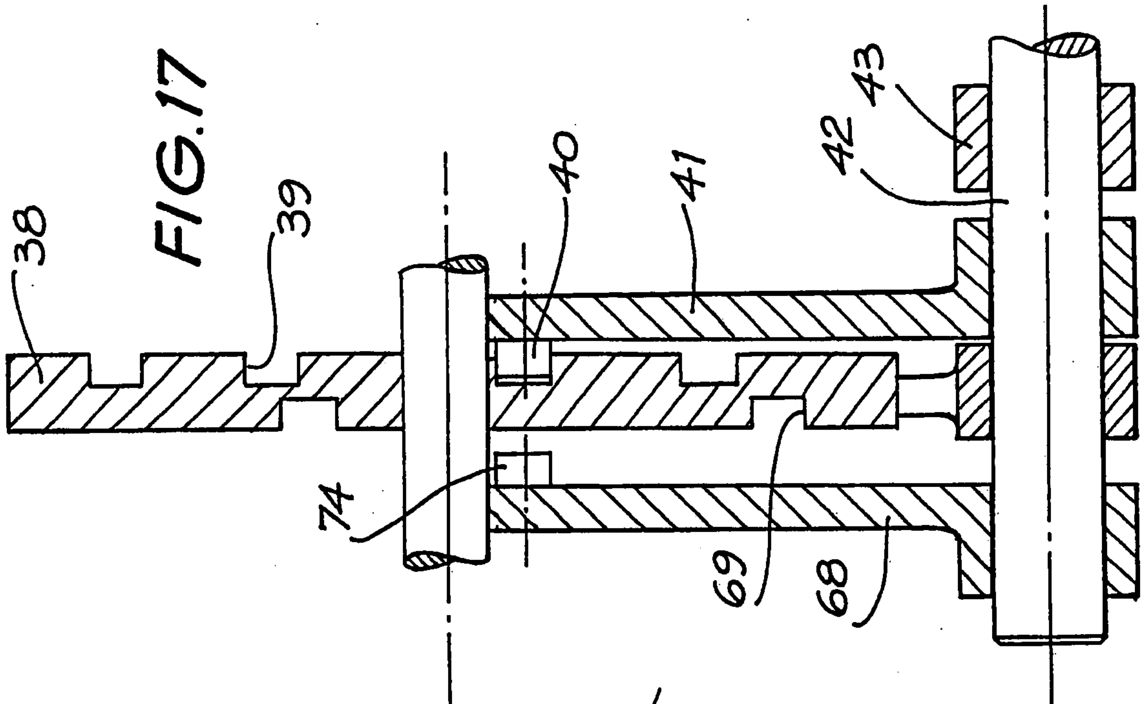

FIG.17

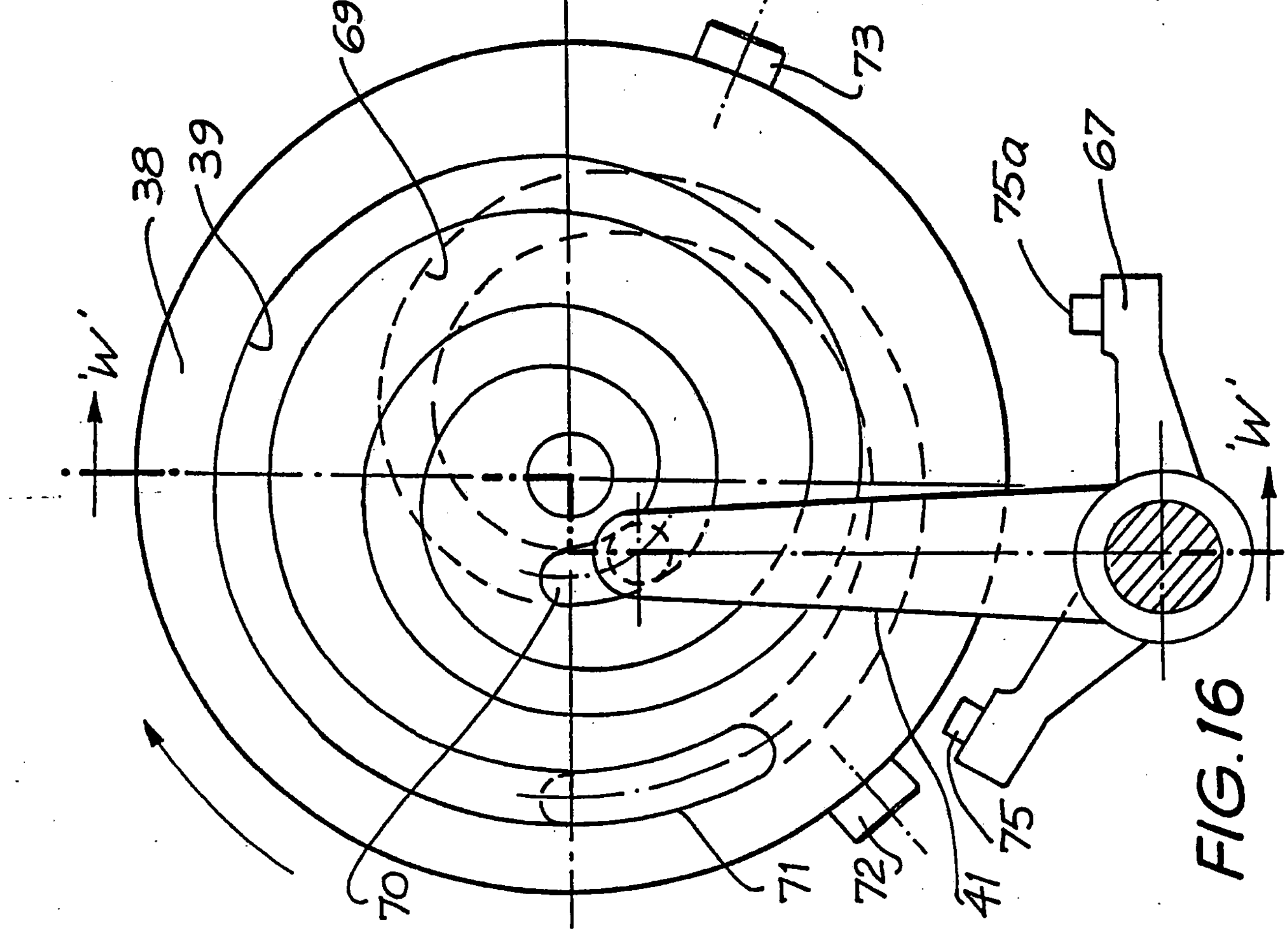

FIG.16

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 89/00094

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] B23D 37/22, B23C 03/04, F04C 02/02, 18/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	B23D 37/22, B23C 03/04, F04C 02/02, 18/02

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	EP,A, 59612 (ARTHUR D. LITTLE INC) 8 September 1982 (08.09.82)	(1-2)
A	US,A, 4615091 (TOSHIKAZU et al.) 7 October 1986 (07.10.86)	
X	AU,B, 35223/84 (574964) (SANDEN CORP.) 23 May 1985 (23.05.85) See Figure 3	(3)
X	AU,B, 76164/81 (539740) (SANKYO ELECTRIC CO. LTD) 22 April 1982 (22.04.82) See Figure 2	(3)
X	AU,B, 89266/82 (552290) (SANDEN CORP.) 19 April 1984 (19.04.84) See Figure 6.	(3)

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 May 1989 (17.05.89)	01 JUN 1989
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	D.G. FRY

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers.........., because they relate to subject matter not required to be searched by this Authority, namely:

2.☐ Claim numbers.........., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.☐ Claim numbers.........., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

Claims 1 and 2 define a method to machine the surface of a multi-turn involute spiral wrap of a scroll type gas compressor component, while Claim 3 defines a scroll type gas compressor component.

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☒ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.